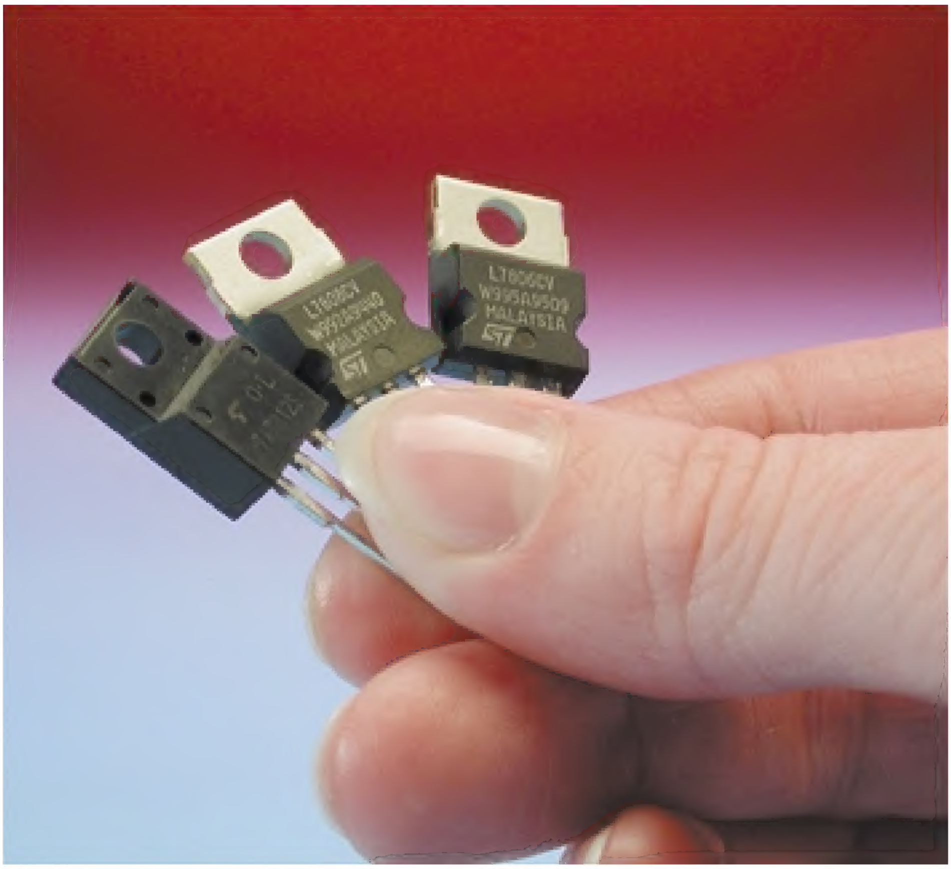
Voltage Regulators

in practice…

From an idea by A. Voigt

Three-legged voltage regulators are known as handy and straightforward components. There are, nevertheless, still a number of interesting facts to report. As always, practice is never quite the same as theory.



Since their introduction, the three-legged voltage regulators have quickly displaced their discretely built counterparts. And with good reason, why be difficult when one component will suffice? They are available for practically any desired output voltage and the performance of the famous 78xx-series is usually more than adequate for most applications. In addition, hardly anything can go wrong, because it comes with a robust thermal and overload protection circuit built in.

The only demand that the three-legged creature makes, is that the unregulated DC input voltage is at least 3 V higher than the output voltage. Otherwise the regulator circuit cannot do its job properly.

These 78xx-regulators are handy building blocks, because they need little real estate on the PCB and require almost no external components. The schematic of a stabilised power supply employing one of these regulators usually looks something like **Figure 1**. The transformer output voltage is rectified with a diode bridge and smoothed with filter capacitor C1. C2 and C3 improve the stability of the regulator as well as its transient response, while C4 acts as the local buffer (reservoir) for the attached load.

The annoying thing about the standard schematic is that it does not make clear what the specific functions of each of the components are. Strictly speaking, it would be better to redraw the schematic of **Figure 1** like the one sketched in **Figure 2**. Granted, it doesn't look quite so neat and tidy, but makes the purpose of the various components immediately clear. Filter capacitor C1 should be placed as close as possible to the bridge rectifier, C2 and C3 should connect directly to the input and output of the regulator and C4 should be very close to the load. At least as important is the requirement that all the 0-V traces are connected at only one common point. The 'cold' side of the output electrolytic is the most appropriate place for this.

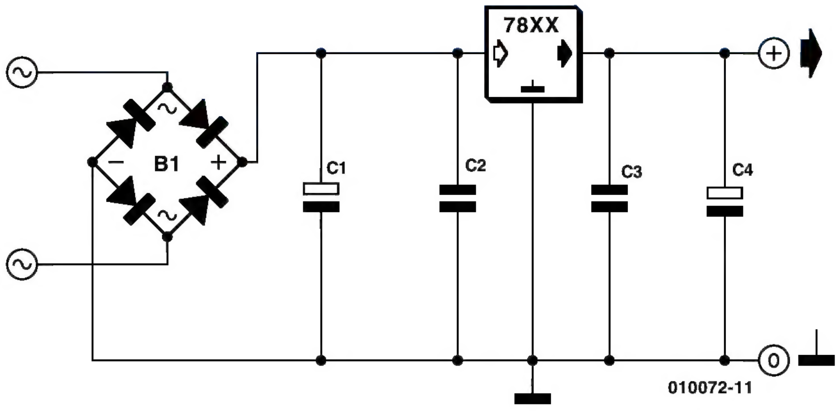


Figure 1. Typical circuit with a voltage regulator from the 78xx-series.

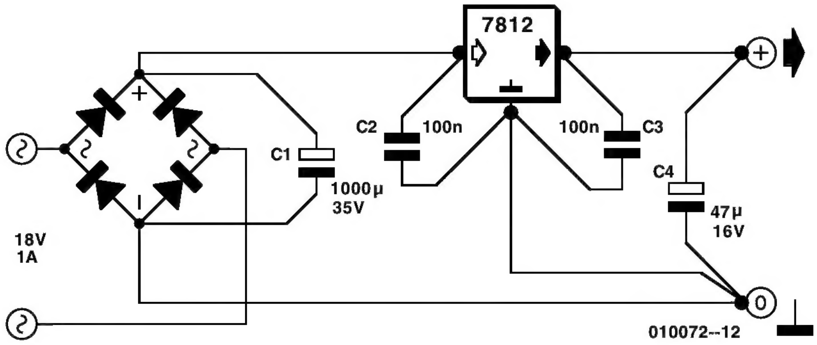


Figure 2. Functionally it would be better to draw the schematic this way.

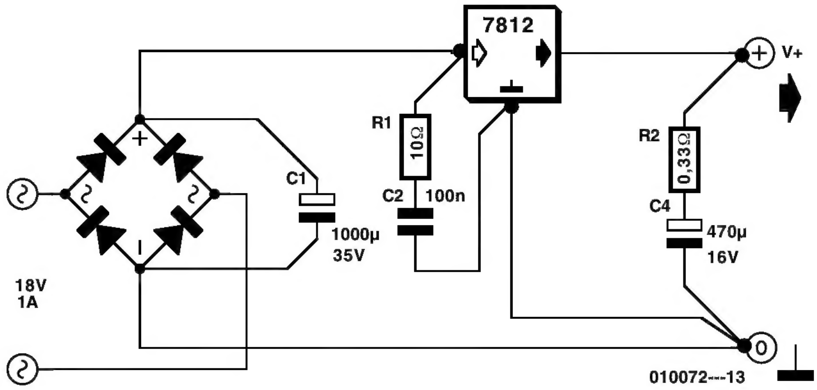


Figure 3. Adding two resistors can improve the transient response under certain circumstances.

The stability, ripple rejection and transient behaviour of the regulator is much better with the design of **Figure 2** than with some haphazard placement of components. This is particularly the case when, due to the circumstances of the PCB, the distance between the bridge rectifier and the load is relatively large.

Some remarks about the value of the capacitors. In practice, a value of 100 nF for both C2 and C3 appears to work well. The value of electrolytic C4 is not really critical and usually varies between 10 µF and 47 µF, depending on the output current. The following rule of thumb can be applied to filter capacitor C1: the value in µF should be at least equal, but preferably a factor of 2 greater, than the current in mA. Thus when taking the 1000 mA in the example of Figure 2, we arrive at a value of 1000 µF or 2200 µF.

Two additional resistors

Although we were unable to repeat some of the things in the Elektor Electronics lab with 100% accuracy, the author claims that the performance of the standard 78xx-circuit can be significantly improved with some small modifications. This manifests itself in a better transient response when the load varies rapidly.

The change does not amount to anything more than the addition of two series resistors for C2 and C4. Capacitor C3 can be omitted without loss of quality and C4 is increased in value. **Figure 3** shows the amended schematic.

It is difficult to come up with a rigorous scientific explanation for the improved properties. A possible theory is that the capacitors and the PCB traces may, under certain circumstances, form LC-loops that can lead to oscillation and cause the voltage regulator to react more slowly. A small series resistor can have a beneficial damping affect. The brand of regulator may also play a role.

Even though the beneficial effects of the series resistors may not be realised under all circumstances, it is certainly worth the effort to experiment with this. The cost is practically insignificant and if this simple method does indeed improve the dynamic behaviour of the regulator, then this is a welcome benefit.

The values for R1 and R2 are difficult to pin down. In the author's prototype, built around a 7812, the values shown in **Figure 3** performed the best. By experimenting it appears that the following principle holds true for R2: as the value of electrolytic C4 is increased, the resistor can be made smaller. The value of R1 is less critical. The advice: just try it in practice.

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